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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,455,284**, on January 16, 2004, by **PENGUIN AUTOMATED SYSTEMS INC.**, assignee of Greg Baiden, for "Underwater Optical Communications System and Method".

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February 14, 2005

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ABSTRACT

An underwater optical communications system and method particularly suitable for use in communications with automated equipment. A series of omni-directional light beacons are dispersed throughout a communications zone. The light beacons are each provided with a plurality of light-emitting elements and light receiving elements which are positioned so that each beacon within the communications zone emits light in all directions and receives light from all directions. A submersible craft is similarly provided with light emitting elements and light receiving elements. The submersible craft is thus always in optical communication with one or more beacons when in the communications zone, regardless of the orientation of the craft and regardless of the position of the craft within the communications zone.

UNDERWATER OPTICAL COMMUNICATIONS SYSTEM AND METHOD

Field of the Invention

This invention relates to communications systems. In particular, this invention relates to an optical communications system particularly suitable for an underwater environment.

Background of the Invention

Many industrial activities are carried on underwater, such as mining, oil exploration and extraction, installation of telecommunications cables etc. Mining in particular is a highly labour intensive activity, especially in an underwater environment because of the difficulty of moving in water and the cumbersome equipment required to enable workers to remain submerged for long periods of time.

Such industrial activities invariably benefit from automation, in both reduced labour costs and increased productivity. In land-based mining it is known to provide robotic mining equipment controlled by radio frequency (rf) communications. This enables a relatively small number of workers to remotely control heavy machinery and equipment located in or on a surface mine (for example in open pit mining). The benefits of automation in underwater activities could potentially be significantly greater, because of the reduced mobility of workers operating when submersed.

However, conventional communications methods are often unsuitable for supporting high bandwidth communications in an underwater environment, especially for the control of robotic equipment which requires the exchange of relatively high data rates with a low error rate for the wireless transmission of multiple video signals. Electromagnetic radiation at radio frequencies travels poorly through water due to rapid absorption and attenuation, which severely limits the ability to provide ongoing communications between a land- or surface-based control centre and submersed robotic equipment used in activities such as underwater mining.

It would accordingly be advantageous to provide a communications system which is reliable, fast and capable of high data rates for use in underwater activities such as mining.

Summary of the Invention

The present invention provides an underwater optical communications system and method, which is particularly suitable for use in communications with automated mining equipment and machinery.

According to the invention, a series of omni-directional light beacons are dispersed throughout a communications zone. The light beacons are each provided with a plurality of light-emitting elements which are positioned so that each beacon within the communications zone emits light in all directions. Interspersed amongst the light emitting elements are optical receiving elements

The invention further provides a submersible craft which, like the beacons, is covered with light emitting elements and provided with light receiving elements interspersed amongst the light emitting elements. The beacons are dispersed about the communications zone such that the submersible craft is able to receive optical signals from one or more beacons, and to send optical communications to one or more beacons, regardless of the orientation of the craft and regardless of the position of the craft within the communications zone.

Preferably the light receiving elements have a sensitivity threshold which can be set according to the ambient light conditions within the communications zone. In the preferred embodiment bit error rate testing and other techniques are used to ensure the integrity of communications.

These and other advantages will become apparent from the description of the preferred embodiment which follows.

Brief Description of the Drawings

In drawings which illustrate by way of example only a preferred embodiment of the invention,

Figure 1 is a perspective view of a communications zone according to the invention;

Figure 2 is a perspective view of a typical light beacon in the communications zone;

Figure 3 is a perspective view of a watercraft according to the invention;

Figure 4 is a perspective view of the communications zone of Figure 1 showing the remote control centre; and

Figure 5 is a schematic view of a communications zone having multiple beacon cells.

Detailed Description of the Invention

Figure 1 illustrates the communications zone 10 in an underwater optical communications system and method according to the present invention. It will be appreciated that the principles of the invention can also be applied to surface-based and space-based communications systems.

The communications zone 10 is defined by omni-directional light beacons 20, which are preferably dispersed generally uniformly throughout the communications zone 10. The beacons 20 may be buoyant and affixed to anchors set on the floor of a body of water, or may hang from a boat or other craft at the water's surface.

In contrast to the 'single cell' communications zone 10 illustrated in Figure 1, Figure 5 illustrates a 'multiple-cell' embodiment of the invention in which the communications zone 50 comprises a matrix of interior light beacons 20a and peripheral light beacons 20b. The light beacons 20a in the interior of thc communications zone 10 are fully multi-directional, and in the embodiment illustrated the light beacons 20b about the periphery of the communications zone 10 are also fully multi-directional, so that the communications zone extends for a distance beyond the peripheral light beacons 20b. It will be appreciated that it is possible to have the

peripheral light beacons 20b emit light only toward the communications zone 10, in which case the communications zone 10 will not extend substantially beyond the peripheral light beacons 20b. The beacons 20 may be interconnected through a network, or may all be connected directly to the control centre 40.

A preferred embodiment of the light beacons 20 is illustrated in Figure 2. Each light beacon 20 is provided with a plurality of light-emitting elements 22 which are positioned so that each beacon 20 within the communications zone 10 emits light in all directions. The light beacons 20 preferably comprise a plurality of fibre optic cables of short lengths and cumulatively formed into a roughly spherical shape, so as to transmit light in all directions. The beacons 20 preferably emit light in the visible spectrum, via light emitting diodes (LED's) or any other suitable light emitting element. Interspersed amongst the light emitting elements 22 are optical receiver elements 24, which may comprise spherical or wide-angle cameras. The optical receiving elements 24 are preferably set back or recessed into the interstitial spacing between the light emitting elements 22, so that light emitted by the beacon's light emitting elements 22 does not add to the ambient light or optical 'noise' affecting the sensitivity of the optical receiving elements 24.

In the preferred embodiment, one of the beacons 20 and the submersible craft 30 transmits at a first wavelength, for example green, and receives at a second wavelength, for example blue; while the other of the beacons 20 and the submersible craft 30 transmits and receives at the second and first wavelengths, respectively. By using two frequencies of light in this fashion, bidirectional communications can occur simultaneously without interference, thus enhancing the communications speed.

Figure 3 illustrates a submersible craft 30 which, like the beacons 20, is provided with light emitting elements 32 and optical receiving elements 34 interspersed amongst the light emitting elements 32. The beacons 22 are dispersed about the communications zone 10 such that the submersible craft 30 is able to receive optical signals from one or more beacons 20 at all times, and to send optical communications to one or more beacons 20 at all times, regardless of the orientation of the craft 30 and regardless of the position of the craft 30 within the

communications zone 10. The light beacons 20 are spaced closely enough to ensure that, within the communications zone 10, the submersible craft 30 is always in optical communication with at least one beacon 20. At the same time, the beacons 20 are spaced far enough apart that they do not significantly interfere with the craft's ability to manoeuvre through the communications zone 10. The ideal spacing may depend upon many factors, including the intensity of the light emitting elements 22 and 32, the sensitivity of the light receiving elements 24 and 34, the transmissivity of the water and the cause of any cloudiness or murkiness, and ambient light levels within the communications zone 10. It may be advantageous to space the beacons 20 so that the submersible craft 30 is always in optical communication with at least three beacons 20; this will allow for positioning/locating the submersible craft 30 by triangulation. The beacons 20 may also be located at varying elevations, to support triangulation for positioning/locating the submersible craft 30 vertically.

The light beacons 20 may powered by an electrical generator contained in a land-based or surface-based control centre 40, shown in Figure 4, and connected to the beacons 20 by optical fibres or electrical cables (not shown). The submersible craft 30 may be powered by any conventional means. The control centre 40 and the submersible craft 30 would in the preferred embodiment each comprise computers, an optical switching system, and an on-board Transmit/Receive link.

The communications methodology may comprise any conventional optical communications system, preferably a packet-based system utilizing optical pulses to transmit the data packets. The particular wavelength of light most suitable for the optical communications may also depend upon the transmissivity of the water, the type of suspension (e.g. organic, sedimentary etc.) causing any cloudiness or murkiness, and the spectral characteristics of ambient light within the communications zone 10.

The preferred embodiment of the invention operates under a token passing system, in which each token is managed by a header and footer. Data, preferably including video from on-board cameras located about the submersible craft 30, is transmitted optically. Data and video information are displayed at the control centre

40 for monitoring each submersible craft 30, and the return data stream controls the submersible craft 30, steering it to a new position or orientation and/or initiating a task.

Preferably the light receiving elements 24 and 34 are coupled to light sensing circuitry having a sensitivity threshold, for example using a Schmidt trigger or comparator to establish a base light level below which the light receiving elements 24 and 34 do not register a light pulse, which can be set according to the average and/or peak ambient light levels within the communications zone. This maximizes reliability of the communications system, ensuring that the light receiving elements 24 and 34 are not saturated by ambient light so that all beacon- or submersible craft-emitted light pulses will be processed as communications signals.

It will be appreciated that the communications system and method of the invention can be used solely to control the submersible craft 30 within the communications zone 10, in which case the craft 30 does not need to be equipped with light emitting elements 32 and the beacons 20 do not need to be equipped with light receiving elements 24. However, in the preferred embodiment the system and method of the invention also provides for communications from the craft 30 to the beacons 20, for example video transmissions, radar and/or sonar telemetry transmissions and the like, in which case both the beacons 20 and the craft 30 will be equipped with light emitting elements 22 and 32 and light receiving elements 24 and 34, respectively.

In the preferred embodiment the invention incorporates bit error rate testing and other techniques to ensure the integrity of the optical communications. However, in the preferred embodiment the submersible craft 30 is designed to automatically stop and sink to the bottom in the event of a communications interruption, to reduce the likelihood of the loss of a craft 30.

Various embodiments of the present invention having been thus described in detail by way of example, it will be apparent to those skilled in the art that variations and modifications may be made without departing from the invention. The

invention includes all such variations and modifications as fall within the scope of the appended claims.

I CLAIM:

1. A communications system, comprising

a plurality of beacons dispersed about a communications zone, at least some of the beacons comprising a plurality of light-emitting elements positioned so that each beacon emits light in substantially all directions, and

at least one submersible craft comprising a plurality of light receiving elements positioned so that the craft receives light from substantially all directions,

whereby when the submersible craft is in the communications zone the submersible craft is in optical communication with at least one beacon for receiving control data from the at least one beacon.

2. The communications system of claim 1, wherein at least some of the light beacons comprise light receiving elements positioned so that each beacon receives light from substantially all directions and the at least one submersible craft comprises a plurality of light-emitting elements positioned so that the craft emits light in substantially all directions, whereby when the submersible craft is in the communications zone the submersible craft is in optical communication with at least one beacon for sending data to the at least one beacon.

3. A communications method, comprising

a. converting data into light,

b. transmitting the light substantially omni-directionally from a plurality of beacons dispersed about a communications zone to at least one submersible craft comprising a plurality of light receiving elements positioned so that the craft can receive light from substantially all directions, and

c. converting the light back to data for controlling the submersible craft.

4. The method of claim 2 wherein the beacons comprising light receiving elements positioned so that each beacon can receive light from substantially all directions, including the steps of :

a. converting data into light,

b. transmitting the light substantially omni-directionally from the at least one submersible craft to at least one of the beacons, and

c. converting the light back to data.

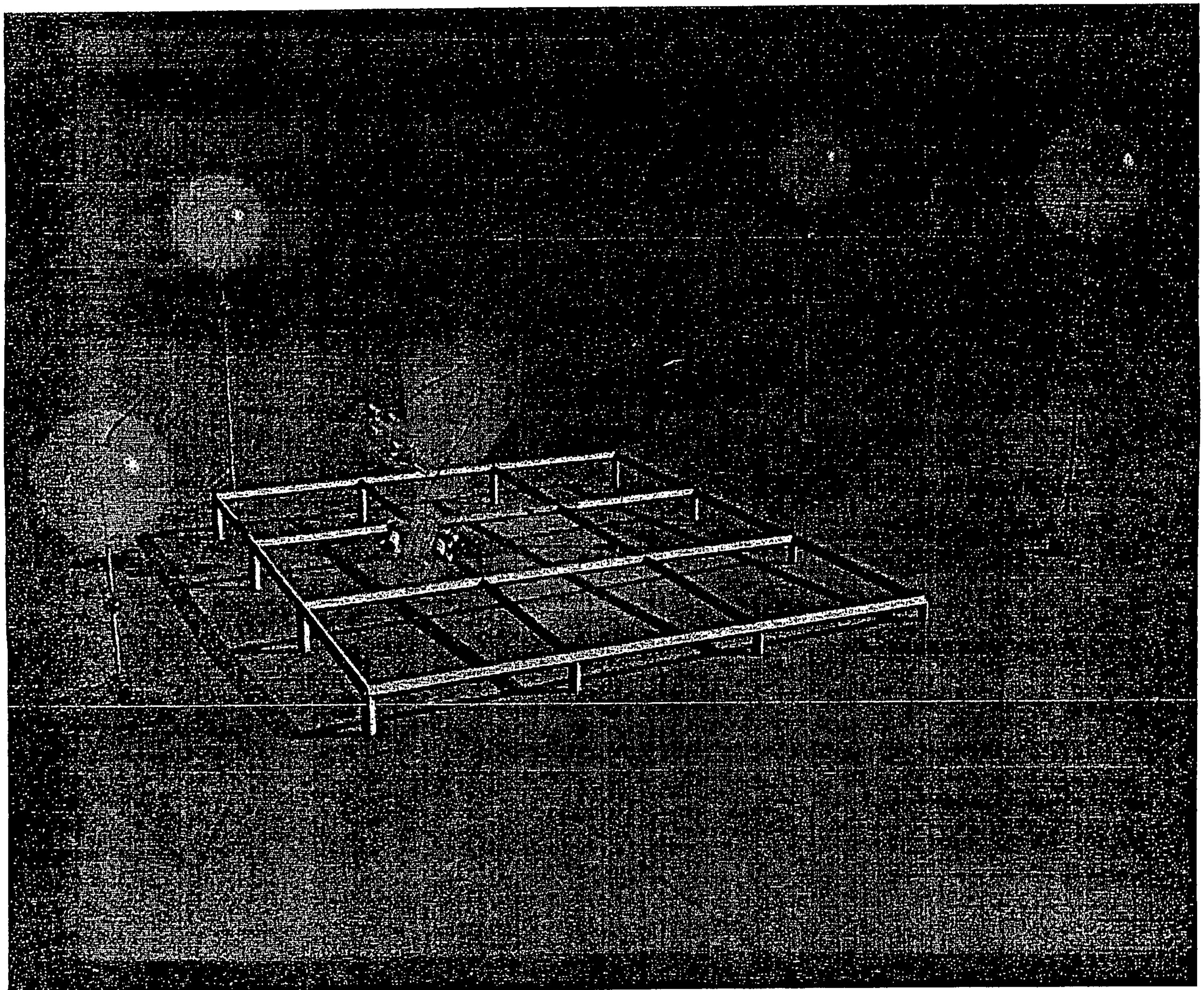

Fig 1

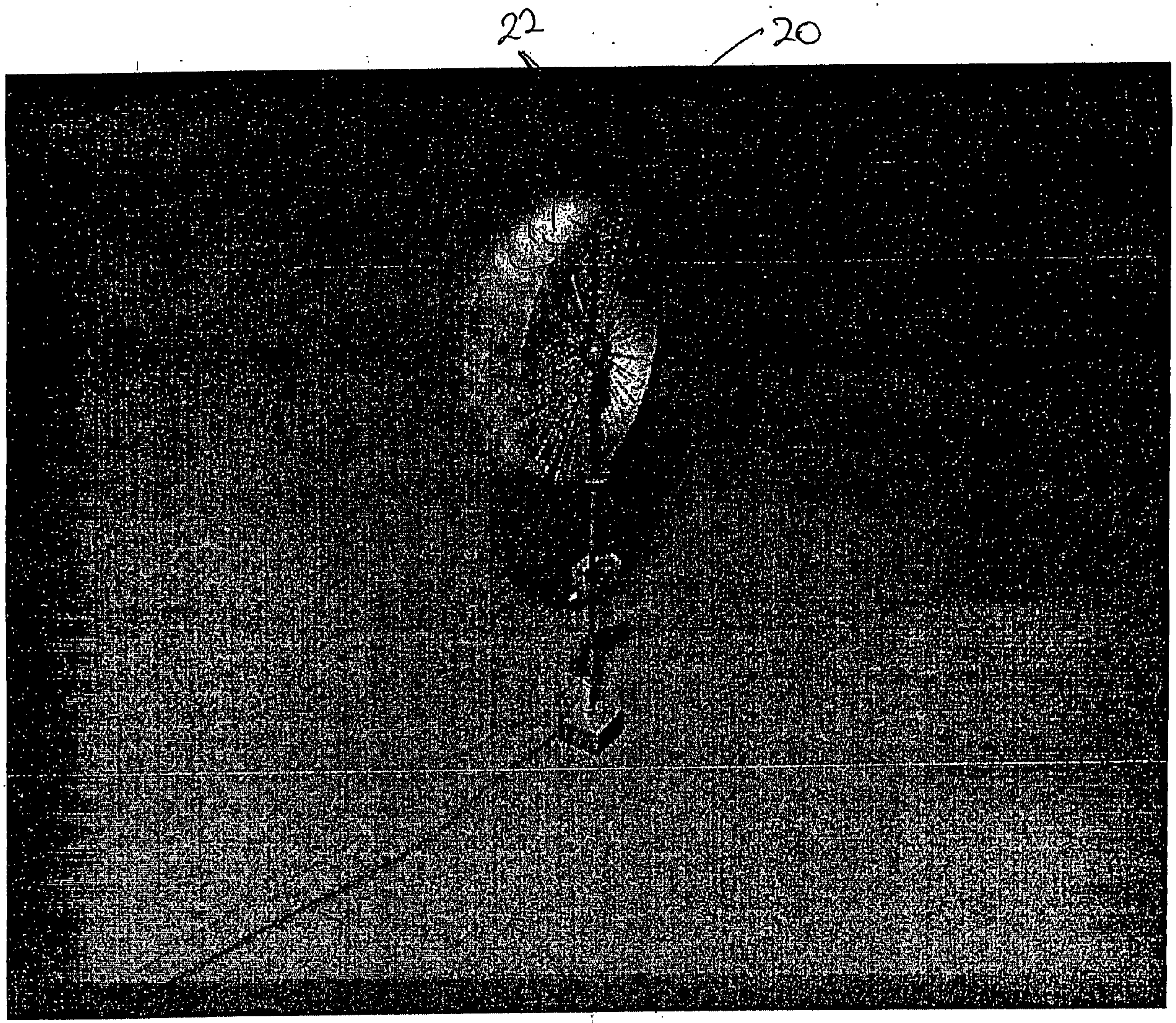

Fig. 2

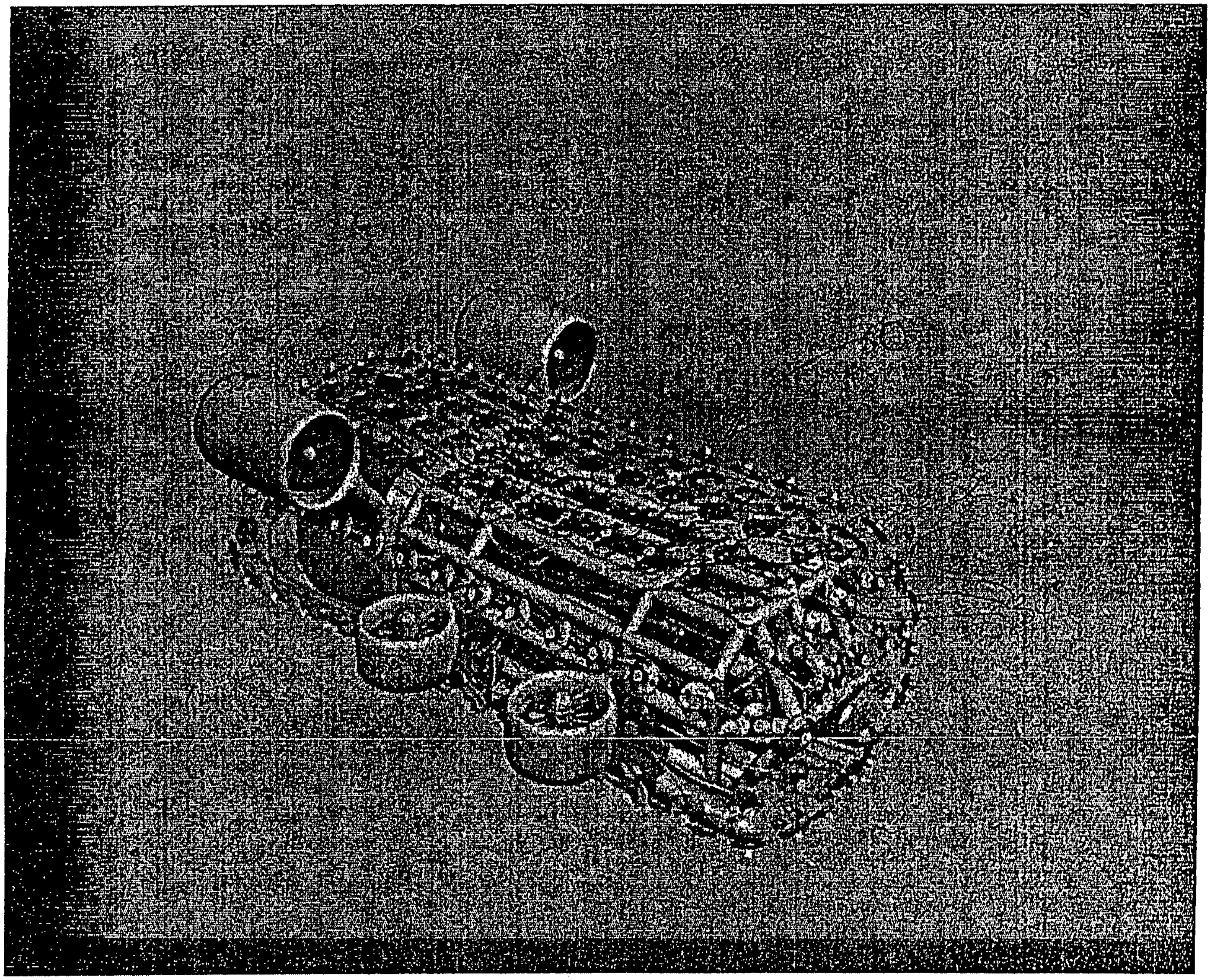

Fig. 3

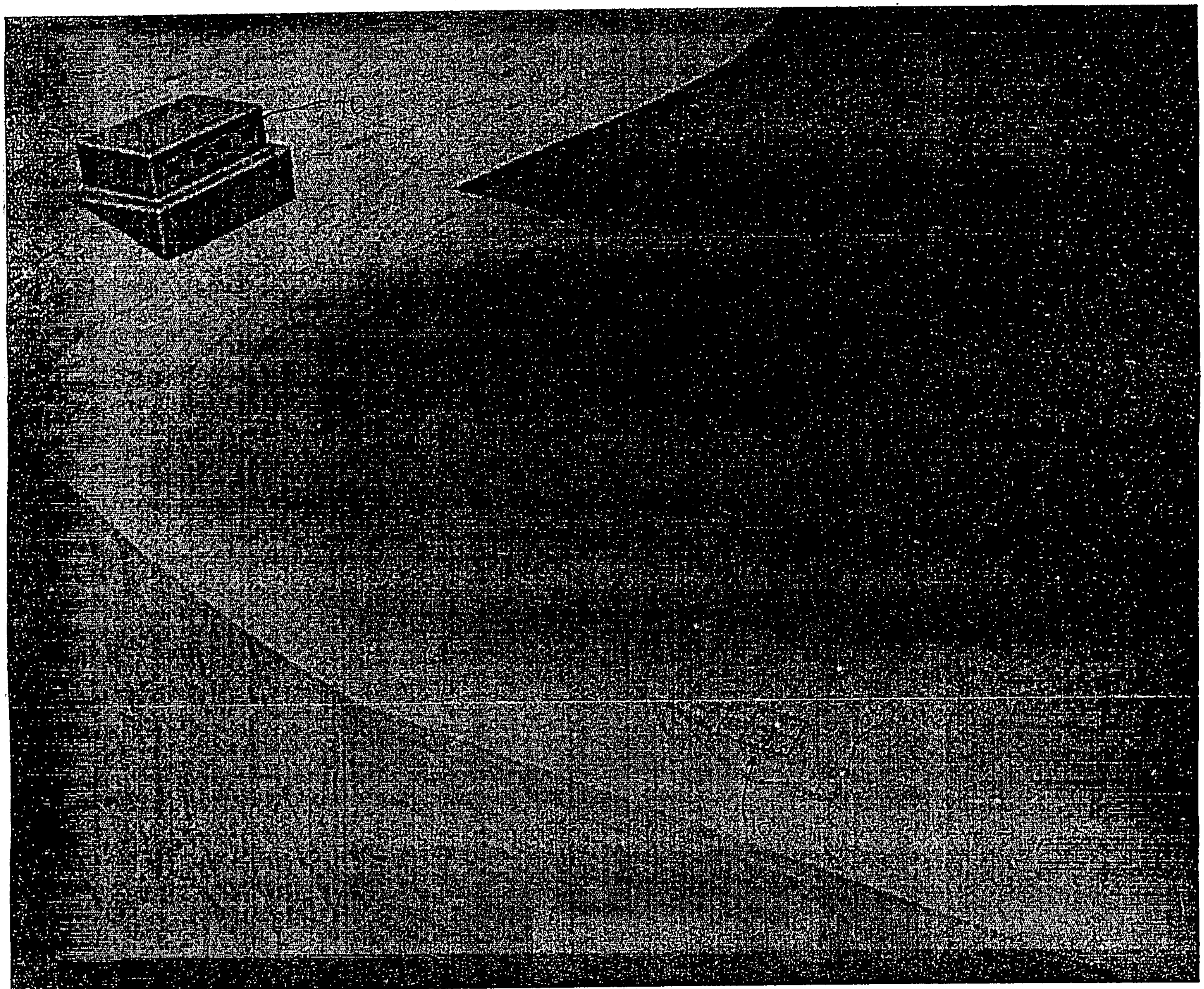

Fig. 4

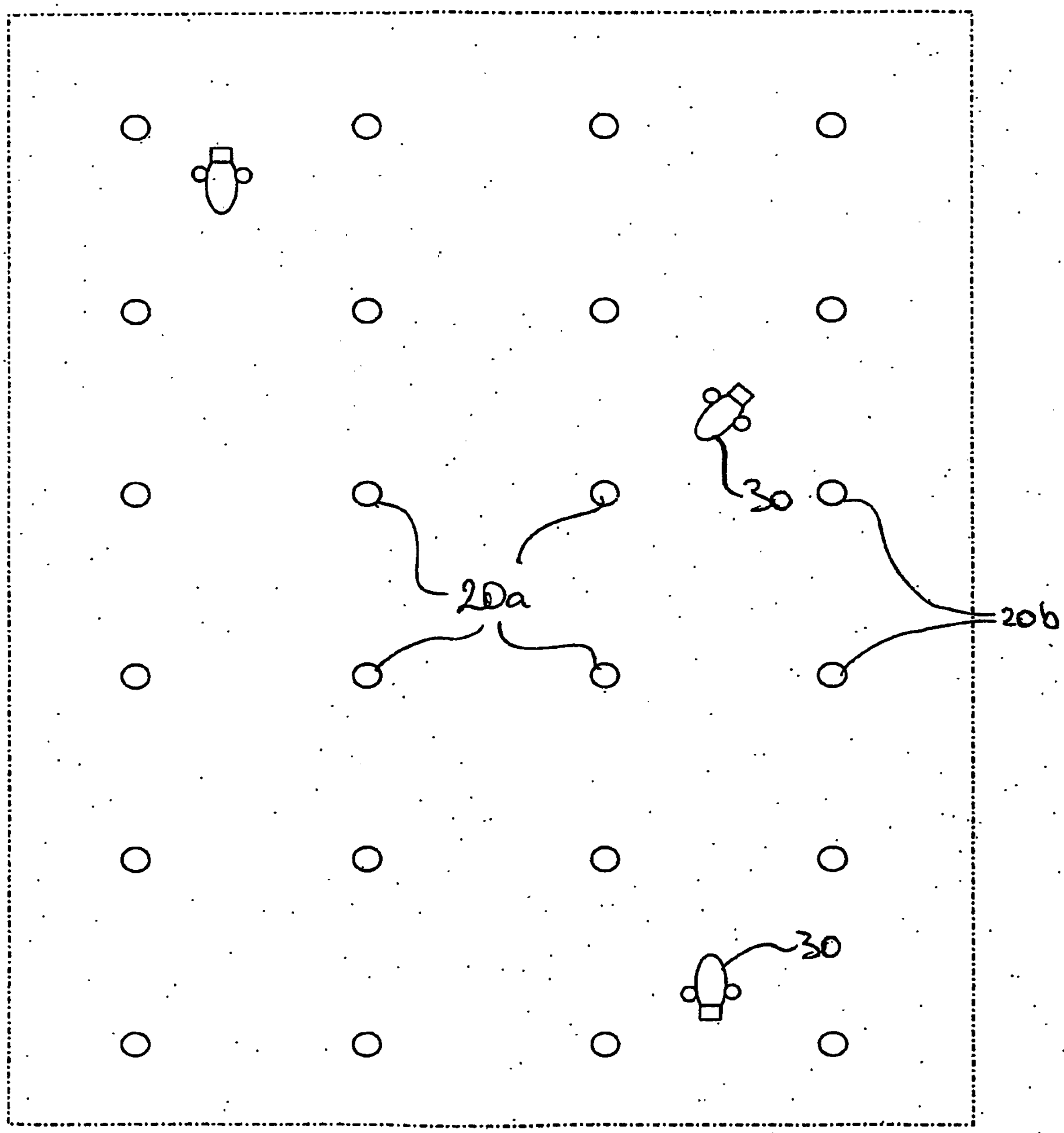

Fig. 5

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